9600 BAUD PACKET HANDBOOK

A handbook for K9NG protocol 9600 baud packet
Version 2.0, June 13, 1994

by Mike Curtis, WD6EHR
7921 Wilkinson Avenue
North Hollywood CA 91605-2210
wd6ehr@k6ve.#socal.ca.usa

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CONTENTS

1 9600 BAUD PACKET - WHY?
1.1 DEFINING PACKET RADIO'S SHORTCOMINGS
1.2 THE CURE

2 WHAT DOES IT REQUIRE
2.1 MODEM
2.2 TNC
2.3 RADIO
2.4 COMPUTER

3 HOW 9600 BAUD PACKET IS DONE
3.1 MODEM
3.2 TNC
3.3 RADIO
3.3.1 PLL MODULATION PROBLEMS
3.3.2 CRYSTAL CONTROLLED PHASE MODULATED RADIOS
3.3.2.1 CRYSTAL SPECIFICATIONS

4 MODIFICATIONS
4.1 RADIO MODS
4.1.1 TXA CUTOFF
4.1.2 FT736 MODS
4.1.3 CRYSTAL CONTROLLED RADIO MODS
4.1.4 IF FILTER CONSIDERATIONS
4.2 TNC MODS
4.3 MODEM MODS
4.3.1 K9NG MODS
4.3.2 G3RUH MODS
4.3.2.1 G3RUH "GARBAGE" MOD
4.4 MODEM INSTALLATION
4.4.1 TNC2
4.4.2 PK-87/PK-88

5 9600 BAUD PARAMETERS

6 TERM GLOSSARY

7 HELP

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1 9600 BAUD PACKET - WHY?

Often heard arguments against higher speed packet: "My TNC works fine at 1200 baud. Why bother with 9600? Besides, I can only type with 2 fingers." "9600 baud is experimental. Only those with pocket protectors and thick glasses should be playing with it on 1.2 GHz or higher." "9600 baud requires too wide a channel for 2 meters."

All of these are wrong! The first is a half truth because it assumes you're the only one typing with 2 fingers; typing with 2 fingers is the ultimate goal of packet; what we're doing is all we ever want to do, and currently packet is in fact working perfectly.

However, this is far from the case. The present packet system is in desperate need of improvement. Packet is capable of far more than what we see it doing today - de facto radioteletype.

The other arguments have no truth to them whatsoever. You can buy working 9600 baud packages from several manufacturers. This is hardly experimental. The experimenting we are doing is in trying to make our radios do something they were not originally designed for. This isn't experimenting - it's thrift.

Although 9600 is more than 1200, the way we do it is more spectrally efficient than the way 1200 baud is done. Believe it or not, 9600 baud actually requires a 12 KHz passband - slightly less than 1200 baud, or NBFM voice. 9600 baud is a better neighbor than either of these!

1.1 DEFINING PACKET RADIO'S SHORTCOMINGS

First, let's quickly analyze packet radio:

1. Short hop simplex works well, but only if the hop is a clean, line of sight path and the channel is not very busy.

2. NETROM/TheNET/ROSE, and other networking protocols work poorly to not at all with multi-hop 1200 baud trunking.

3. Mail often requires days, or even weeks, to reach its destination, IF it ever gets there!

4. Ruling out HF packet (which isn't such a bad idea anyway :-), we're limited to NETROM over radio paths of a few hundred miles or so if we want to do packet that makes the trip in a reasonable time.

5. Other areas, like Europe, have far more sophisticated and efficient packet trunking systems and user access channels that work.

6. Urban packet channels are overcrowded to the extent that many have thrown in the towel.

7. Even with packet <--> internet gateways, inefficient links into these cause many problems.

1.2 THE CURE

Now let's dream a bit:

NEWS FLASH! WD6EHR's fairy godmother grants Mike several wishes. After the obvious wishes have been carried out, a slip of the tongue grants us a super-duper packet system. (HEY!! I wanted a new pair of socks! My old ones are gettin' kinda gamey!!)

When I wake up in the afternoon (hey - it's my dream), I work FR0CK in France, TR0PIC in Gabon, L0RRY (Moe) and CU2LY (Joe) (and SH3MP breaks into our round-table conference bridge, too), doing all of this via our high-speed packet multi-megabit world-wide trunking system.

I receive packet mail at my station within seconds of its being posted. We have conferences with more than 100 packeteers on a single 2 meter frequency, and these are linked to other conference bridges worldwide.

Large files are being transferred between local stations, and are coming in via the high speed (10 MBPS) trunk. I'm getting the newest PD version of "Super Italian Brothers", which was just finished 30 minutes ago by an Australian programmer in Japan, so I connect to our _L_O_C_A_L_ fileserver (who got it automagically off the master trunk) and download a copy of this 600K file. This takes me all of 10 minutes on our 9600 baud user channel (using auto-compression, of course). If I'm in a _real_ hurry, I use the local spread spectrum 10 megabit/second user port.

In the meantime, I chat with a few of the locals (W1MPY in Baastin, Mass, and K0OKY in Dayton, OH) on our linked conference. While in QSO, I open another session and look up these guys in the central nameserver and data base, and find that W1MPY used to be a shipmate of Popeye Doyle, served in the military with Bill Clinton, and was originally licensed in the '60's as H1PPY; and K0OKY owns a comb factory.

I want to use my little T-1000 laptop XT to do some SuperWhizBang AutoCAD (which requires a full-blown SPARCstation), so I remote execute

this on another machine via high speed packet, and receive the results on my printer, as if it had run on my little 4.77 MHz XT-compatible! Wow! Talk about a cheap upgrade :-)

-o-

Packet has capabilities far beyond simple text applications, such as file transfer, automatic worldwide routing, mail and news transfer, remote execution (allowing you to use my computer to run software, and then send the results back to yours), nameservers (callbook on a CD is an example of this), remote printing, and even linking several smaller computers to undertake a much larger task than any of these would be capable of alone. These are all tcp/ip servers, and work best with higher data rates.

-o-

What would make all of this possible? The software and protocols are either available or in the works. What is missing right now is a suitably connected high speed packet network. A multimegabit world-wide trunking system could tie all the metropolitan areas together. These would be served by metropolitan area networks, with efficient 2 meter 9600 baud local access channels, and higher speed user ports, i.e. 56 kB plus, on higher frequencies.

Am I dreaming? Too many brewski's? Not at all - this is all possible TODAY using EXISTING, INEXPENSIVE technology! We don't need any magic - just a small fire under certain easy chairs - YOURS! And do you know who I'm talking about? All of you who think I'm talking about someone else! Yes, with POPULAR support, this isn't just possible; it's easy.

Two meters is a logical place for end users. The band is amateur-only and is one of our most consistent and predictable bands. It is also not shared with radar, unlike 222, 440, etc. 9600 is for practical purposes top speed on 2 meters with 15 to 20 KHz channel spacing and typical voice grade radios. It's much more efficient than 1200 baud, and therefore a much better use of our precious radio spectrum. Being FSK, it actually requires slightly LESS bandwidth than voice, or typical 1200 baud AFSK packet, in spite of its greater baud rate. We have actually measured 9600 baud running at the recommended 3 KHz deviation as ~12 KHz wide, with negligible energy outside this passband. Most 1200 baud signals are about 13 KHz wide, with a few of the "plug and play" crowd as wide as 30 KHz!

We also need a spirit of cooperation and a return to the original intent and purpose of the ARRL (American Radio RELAY League). The ARRL was originally founded before we were aware of HF propagation. Messages had to be *relayed* from one station to another. The ARRL was actually an early form of a network!

The first step in a higher speed data network is getting USERS "up to speed" - and that is the main purpose of this manual.

In undertaking this project, I have made certain assumptions. A childs health primer would most certainly not include a plethora of medical terminology; nor would a PhD textbook be written at first grade reading level. The first would be beyond the understanding of the readers. The latter would be cumbersome and certainly inadequate for its purpose. I assume my audience has a reasonable electronics, technical, and packet background. If you feel uncomfortable around terms like "OSCILLOSCOPE", "MODEM", "TEST POINT", "DISCRIMINATOR", "VARACTOR", or "MODULATOR", you probably should not attempt modifying radios.

2 WHAT DOES IT REQUIRE

All right, Mike - I'm sold! What do I need?

2.1 MODEM

9600 baud packet requires a modem. The most common varieties are k9ng, g3ruh, TAPR, and DRSI. The k9ng was distributed by TAPR, but has been discontinued in favor of the much improved TAPR modem. DRSI has an excellent 2 chip 9600 baud modem in their DPK-9600 TNC. DSP modems can also do 9600 baud packet.

The TAPR modem kit is the latest from the folks at TAPR. We've found it works as well as the g3ruh modem, and seems to do a bit better with weak signals.

The g3ruh is also a good performer, and has a lot of test points.

The k9ng was a low cost means of getting into 9600 baud. It is less forgiving of group delay and amplitude variations in the receiver. Group delay is a form of phase distortion inherent in many IF filters when approaching passband edges. Voice tolerates phase delays; data doesn't. The k9ng modem can be optimized, detailed later in this manual. However, we've found that the other modems will still perform better.

The DRSI DPK-9600 is a TNC2 clone (yes - a TNC, not a PC card) running at 10 MHz, and using a 2 chip modem. I have been using this for around a year, and am very impressed with its performance. The modem uses receive signal compensation, which is really where waveform tweaking should be done. Also, it will run 38k4 from the serial port. When used with a 16550afn UART, this thing really screams! This modem will do 4800, 9600, and 19,200 baud, requiring only a header change.

The Kantronics D-410 radio has a data slicer, and has been used with raw data (without a modem). However, this configuration is not compatible with any of the above modems, but could be used in a point to point service, such as trunking. This configuration is quite broadbanded (around 100 KHz channel width is required!), as no waveform shaping is used. This means more bandwidth and power are required for the same coverage.

2.2 TNC

Most TNC's are capable of 9600 baud. A notable exception is Kantronics KAM/KPC line. The Data Engine will do 9600 baud and much higher. If your TNC has a "9600 baud radio" setting (as opposed to 9600 baud serial port to the computer), it will work with k9ng/g3ruh modems.

2.3 RADIO

You can NOT use the radios microphone and speaker jacks for k9ng or g3ruh format 9600 baud packet. PERIOD! So don't ask!

Why, you ask? (wise guy...) Well, the normal receiver signal path is designed for voice. Data doesn't make it through. The transmitter microphone and receiver speaker audio is preemphasized and deemphasized.

Transmitter pre-emphasis boosts frequencies at +6 db per octave (which is the characteristic of phase modulation), and receiver de-emphasis cuts higher audio frequencies. Amongst other things, this gives a better signal to noise ratio.

HOWEVER, like all filters, it also SHIFTS the PHASE, verboten with data. Why? (Hoo boy! You shore ask a lotta ferschlugginner questions!) Your former digital 1 in the 112th position in the wave train is now delayed to where the 113th position _should_ be, etc., and your data is corrupt! (Hey, I didn't know data could be bribed :-)

(How much does it cost to bribe binary data? 2 bits, of course. Some higher priced data requires 4 bits before it'll nibble, or even 8 bits before it'll byte ;-)

All of these 9600 baud modems use "FSK" (Frequency Shift Keying; it shifts between 2 RF frequencies, e.g. 145.007 and 145.013 MHz for a nominal center frequency of 145.01). Bell 202 1200 baud AFSK (Audio Frequency Shift Keying) modems, like your TNC has, uses 1200 and 2200 Hz AUDIO tones FM'd (or AM'd) onto a carrier.

Translated into simple English, this means you need direct connection to the FM modulator varactor and FM detector.

The Alinco DR1200 has a mod that uses the mic jack, but when you do this mod, it's no longer a "mic" jack, but is now an FSK data port. You're better off wiring the dataport through something else and retaining your microphone jack for microphone and 1200 baud.

The easiest way to use 9600 baud is with a Kantronics D-410 or TEKK TNET Micro or TNET Mini. These are plug and play and need no modification. The next easiest are multimode rigs and some of the commercial radios, such as Motorola Mitrek, Maxar, and others with very simple IF's. I've heard very good things about the Mitrek and 9600 baud.
****

2.4 COMPUTER

Any computer can be used for 9600 baud, as long as it has a serial port. However, it will work better if you run it at 19,200 baud or higher, and have a 16550AFN UART. This has an internal buffer, which caches bits that would ordinarily be lost while waiting for the computer to tell the TNC (in my best "Quickdraw McGraw") "Hold on just a minute thar, Baba Louie - _I'll_ do the thinnin' 'roun' here", and (in my best "Baba Louie"), "OK, Queeksdraw, but I just dropped some beets you throw at me."

Of course, your software must support the 16550AFN, but more and more software these days does. Most versions of the popular ka9q NOS software support the 16550AFN.

3 HOW 9600 BAUD PACKET IS DONE

With mirrors, of course :-)

3.1 MODEM

The PacComm NB96 g3ruh modem board plugs inside many TNC,s, such as TNC2 clones (MFJ 1270B, etc). There is a special modem available for the MFJ 1278T (and maybe it'll work with other MFJ's, too???), from MFJ. It takes the place of their 2400 baud modem.

Likewise, the TAPR modem board fits inside many TNC's, and uses the TAPR standard modem disconnect header.

The k9ng modem kit (no longer available, but included for reference) is cheaper than the g3ruh modem, but is fussier about receivers. If the radio you want to use has a pretty broad receiver passband, it'll work almost as well as the g3ruh. If the receiver is tight, the k9ng will be noticeably poorer. However, this can be somewhat ameliorated (hey - no wiseguy remarks about "Earhart") by widening the k9ng's receive filter, as detailed in 4.3.1.

Normally, you'll want to use the TNC's keying circuit. With the g3ruh, you have no choice.

3.2 TNC

PacComm, Kantronics, Gracillis, MFJ, and probably others have TNC's with 9600 baud G3RUH modems built in. Check the ham mags, call the manufacturers, or contact your local dealer for information.

DRSI has the DPK-9600 TNC with their own 9600 baud modem built in. This has only the FSK modem for 4800/9600/19200 baud - it has no 1200 baud AFSK modem.

Many of us will take the route of installing our own modems. These may often be installed internally. Sometimes it may be necessary or desireable to install these externally.

As with all RF environment installations, shielding is important. If an external box is desired, it really should be a metal one. Shielded cable to the radio is mandatory - it will not work without it. Some kind of RFI-proofing of the modem disconnect cable is needed as well. This should be kept as short and unexposed as possible.

The G3RUH modem requires you to use the TNC's keying circuitry, and this is recommended for the k9ng as well. If you do this, don't cut the PTT line on the modem disconnect.

3.3 RADIO

Many modern rigs are true FM, and it's very simple to add a 9600 baud

port. You need only a couple of internal connections and de- coupling components to bring out the "raw" transceiver: the direct detector output and direct FM modulator input.

If a rig is modulated in a crystal oscillator (most multimodes and many older PLL synthesized radios are), it's simple to add 9600 baud. If it's modulated in the PLL (as many today are), this is a little more tricky, as the PLL tries to track the modem's TXA! If the loop time constant is 30 Hz or less, it'll work. If it's much above 30 Hz, the modem TXA will be distorted by the PLL. This is especially critical for those working Uo22 (which has a time constant of 90 Hz!)

Most rigs of recent vintage use receiver chips, such as TA7761F/P, LA5006M, LC7532M, TK10420, TK10424, MC3357P, and others. Note: ALL of these chips use pin 9 for the detector output. Others may use different pins for discriminator output.

Transmit "audio" is injected through a 5 to 10K resistor into the modulator. This is typically a varactor diode in a transmit oscillator stage, and is pretty simple to find, by simply tracing forward from the microphone.

3.3.1 PLL MODULATION PROBLEMS

Radios modulated in the PLL present a paradox. Because the PLL is designed to keep the frequency from changing, they attempt to correct the modulation. The PLL loop has a time constant to minimize this. However, this also affects how fast the PLL locks when it changes frequency. This affects your keyup time.

If the time constant is slow (30 Hz), 9600 baud FSK is passed cleanly. However, this makes the PLL rather slow going from receive to transmit, and back to receive.

If the time constant is increased, our keyup/recovery time is improved. However, the PLL tries to track the low frequency component of our 9600 baud signal. This results in phase distortion of our 9600 baud signal.

One way around this is to inject the low frequency component of the modem signal into the PLL reference oscillator to compensate for this tracking. This should be done empirically, looking for the best eye pattern on a known good receiver or service monitor. This is not a simple procedure, and is not recommended for those without experience.

*** NOTE: You will need a spectrum analyzer to do this. Adjusting the PLL can create psurious emissions! ***

All multimode radios I've seen use a separate crystal oscillator for generating FM, so their PLL is usually set for fast keyup. For example, my Icom 290H is usable with TXD 3, as short as I've been able to go with any radio. Many older FM rigs also use a separate crystal oscillator, such as the TW4000, and should be good at 9600 baud.

3.3.2 CRYSTAL CONTROLLED PHASE MODULATED RADIOS

We have found that true FM rigs using varactor modulation in a crystal oscillator stage tend to work best. They tend to have very linear FM. Multimode rigs are usually of this type, and usually have a little wider IF filter (i.e. CFW455E) and pass data with less distortion.

If your rig is crystal controlled, it can be made to work. If it's a true FM rig, it's simply a matter of connecting directly to the FM modulator. This will always be in a crystal oscillator stage. If it's phase modulated (in a non-oscillator stage), you will need to add a varactor modulator in the transmit crystal oscillator. This is not too difficult. Also, the crystal should be a "fundamental" type. These are easier to FM than overtone types. When you order the crystal, the manufacturer might be able to help.

3.3.2.1 CRYSTAL SPECIFICATIONS

Here's a tip I got from Frank W7ZTA: Ordering a proper crystal for FM is important, and can sometimes be a sticking point with crystal

manufacturers, who may want to charge extra for "designing" a "custom crystal". However, there is a way around this. Order a crystal with similar characteristics that is used in a rig that does true FM. Frank did this when trying to improve the Icom 22A's transmit waveform and stabilize the oscillator. The IC22A uses a x8 multiplier. The KS-900 uses a x27. He ended up ordering a crystal for the TEKK KS-900 (a 440 MHz data telemetry rig with similar crystal specs. The transmitter local oscillator runs in the same frequency range, etc.), which FM's the transmit crystal very linearly, cut to 27/8 the frequency he wanted, i.e.

(144.99 * 27)/8 = 434.97 MHz.

He reports the transmit eye pattern is much improved!

4 MODIFICATIONS

There are some 9600 baud ready radios, such as the TEKK TNET Micro and TNET Mini, Kantronics DVR 2-2 (not recommended), and D-410, but most of us will be using our existing radios for 9600 baud packet. Here are some specific "mods" and tips.

4.1 RADIO

4.1.1 TEKK KS-900 (TNET Micro) and KS-960 (TNET Mini)

For many rigs, a TXAudio attenuator is necessary to swamp the modem's 4 volts peak to peak transmit audio down into the range needed for 3 KHz deviation. For example, the TEKK KS-900 (TNET Micro) and KS-960 (TNET Mini) need 50 mVRMS, so we use a 470 ohm resistor in series, and a 39 ohm resistor across the radio's transmit input and ground. This assumes the modem's transmit audio output wants to terminate into 500 ohms. Check your modem's documentation.

Some modems have a lower output, such as the MFJ-9600. Adjust the attenuator accordingly.

4.1.2 OTHER RIGS

These mods are non-destructive unless you QSLF (solder with your left foot :-) - your rig still does whatever it did before. Unless otherwise noted, these mods are untested.

Icom IC290H/V: RXA may be obtained at IC12, pin 9, on the main board; TXA may be injected at D-3 cathode on the main board, through a 680 ohm resistor. This one is my personal 2 meter 9600 rig, and works great!

Icom IC28A/E/H : RXA may be obtained at IC1, pin 9, on the RF unit; TXA may be injected at R-45, at the end NOT connected to trimpot R-100

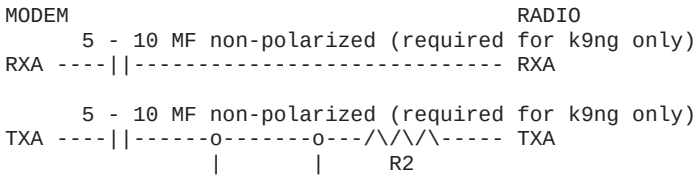
Icom IC3200A/E: RXA may be obtained at IC1 pin 9 (main board) - this is a common receiver chip for both bands; TXA may be injected at D3 cathode (VHF) and D1 cathode (UHF).

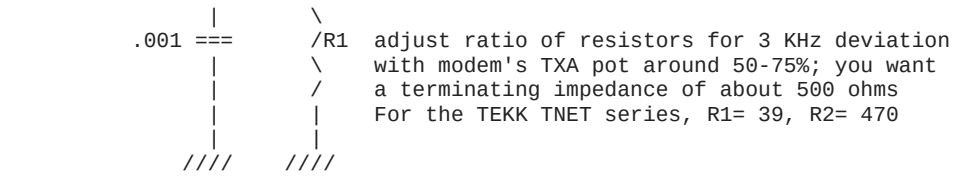
Kenwood TM221, TM321A, TM421: RXA may be obtained at IC1, pin 9 (IF board); TXA may be injected at connection #7 on the VCO assembly on the TX/RX unit.

TR751: RXA may be obtained at IC2,pin 9 on the RX unit; TXA may be injected at D21 cathode on RX unit.

Yaesu FT-207: Discriminator output - pin 9 of Q104. FSK input: wiper of VR201. Courtesy of Tony, ah6bw

Use the following circuit to couple the modem to the radio.

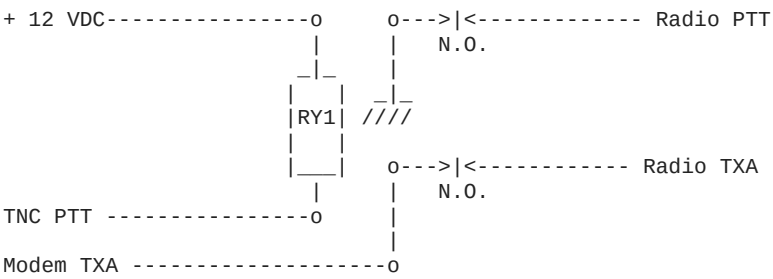




note: Fixed resistors are more reliable than a potentiometer.

4.1.1 TXA CUTOFF

You may need to remove the TXA's idle tone from your rig if you use it for voice, or if it's FM'd in the PLL, etc. This simple circuit will handle the chore. Call me old fashioned, but I also like the audible click that lets me know when the rig is transmitting.



RY1 is a double pole 12 volt relay. Use the normally open contacts

This removes the modems TXAudio line from the radio's modulator when you're not keying from the 9600 baud TNC. If you're using the same TNC for 1200 and 9600, make sure you remove the PTT signal from the relay! Otherwise you'll pick up a nice 4800 Hz "tone" from the 9600 band modem. The relay adds an insignificant keyup delay.

4.1.2 FT736 MODS

FT736 & 9600 Baud Operation

by James Miller G3RUH

These notes tell you where to get FM RX audio direct from the discriminator, and where to modulate the FM TX varactor directly. These mods are non-destructive and take no more than a few minutes. The signals bypass the "DATA SOCKET" for high grade FM operations.

The RX mod is suitable for:

* UOSAT-D 9600 baud downlink and terrestrial links
* 1200 baud AFSK/FM Standard Packet - BUT IT'S UNSQUELCHED.

The TX mod is suitable for:

* FO-20/PACSAT uplink (1200 bps Manchester FM)
* UOSAT-D 9600 baud uplink direct FSK and terrestrial links
* 1200 baud AFSK/FM Standard Packet.

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FT736 - FM Direct from Discriminator

Detected FM direct from the receiver discriminator is available from the RX UNIT at the junction of R91 and C83. These components are shown in the top right-hand corner of the schematic.

Proceed thus:

1. Disconnect FT736 from the mains electricity. (Safety).

```
 2. Remove top cover only.
 3. RX Unit is the vertical module on the left.
 4. Locate R91 which is about 25mm from the top, 50mm from the
radio rear.
    the resistor is "on-end", and near a couple of glass diodes.
 5. Scrape any paint off R91's free end and wet with solder.
 6. Your RXaudio lead should be a fine screened cable;  connect
  the inner to R91, and the outer braid to a ground point (e.g.
  can of TO09)
 7. Route the cable out though any convenient aperture in the case.
 8. The discriminator sensitivity (FM Normal) as about 6 kHz/volt.

Important note on 9600 Baud Use
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Most FT736 receivers are fitted with an LFH12-S IF filter for FM.
(CF01 at the top front of the RX Unit).  This is a 12 kHz
bandwidth filter which is a little narrow for 9600 bps FSK
operation.  It is recommended you change this to 15 kHz or better
still for UOSAT-D use, 20 kHz bandwidth which will allow more
tolerance for doppler shift, and give a far better "eye".
Suitable filters are: LFH-15S or CFW455E, and LFH-20S or CFW455D.
The first of these is a Yaesu spare part, and is often already
fitted.  Try the standard first and see what happens;  these
filters have moderate part to part variations.



FT736  DIRECT VARACTOR FM MODULATION
------------------------------------
Refer to the circuit diagram; inject your TXaudio at the junction
of R32/C29 on the TX Unit.  The signal level at this point should
be 800 mV peak-peak, and will give +/- 3 kHz deviation.  DO NOT
EXCEED THIS LEVEL.
Set Mic Gain to min.

Modulating the FM transmitter this way you get an LF response
down to 18 Hz (at which point the associated synthesiser PLL
begins to track the modulation), and an HF response which is flat
to some 10 kHz.

Proceed thus:
 1. Disconnect FT736 from the mains electricity. (Safety).
 2. Remove top cover only.
 3. TX Unit is the module flat on the left (not the one tucked
 down the side vertically).
 4. R32 is just to the left of the rectangular shielded
enclosure.  The resistor is "on end".  Scrape any paint off
the free leg.
 5. Your TXaudio lead should be a fine screened cable;  connect
  the inner to R32, and the outer braid to the adjacent
enclosure.
 6. Route the cable out though any convenient aperture in the
case.

 7a. 1200 BAUD G3RUH PSK MODEM: TXAudio of 800 mV pk-pk can be
  obtained by
     adjusting the components C9= 1uf, R3=47k, R5=infinity (i.e.
     remove).
     C10 stays at 10nf (0.01uf).

 7b. 9600 BAUD FSK MODEM: Adjust TXAudio level with VR1

 Notes compiled by G3RUH @ GB7SPV 1990 Mar 16
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4.1.3 CRYSTAL CONTROLLED RADIO MODS

If your rig is true FM (varactor modulator in an OSCILLATOR stage), try injecting TXA through a 5 mF cap and a 22k isolation resistor into the varactor at the same point voice audio is brought in.

Many crystal controlled rigs are phase modulated and need a varactor modulator added to the transmit crystal oscillator.

Use an abrupt junction type, such as the MV2105 (available from Kantronics), and adjust the capacitance in the crystal circuit to compensate for the additional C of the varactor. If there are fixed caps, remove or pad them. If not, change the trimmer to one of a lower minimum value.

You'll need to bias the varactor. I've used the transmit oscillator Vcc and a 20K trimpot to ground, feeding bias through 2 10 to 47k fixed resistors, feeding the modem TXA thru a 5 to 10 uF cap to the center junction of these, and feeding the free end to the cathode of the varactor. The bias needs to be adjusted for best received eye pattern on a service monitor or receiver. the lower the voltage, the more delta-C (change in capacitance), but it's also more prone to drift and chirp - so try to keep this around a couple volts or more if at all possible.

Modifying the IC22A for 9600 baud operation

by Mike Curtis, wd6ehr, Dave Shalita, w6mik, and Frank Andersen w7zta

This is one of the more difficult rigs to modify - most are even simpler! This mod will make your IC22A into a dedicated 9600 baud packet radio. Components with * are added to the crystal board.

Remove the trimmer capacitor (15-30 pF) for the transmit crystal socket you'll be using for 9600 baud. Replace with the circuit below. The 4-20 pF trimcap should be a good quality ceramic or other low-drift trimmer. Sorry - Radio Shack doesn't have anything suitable.

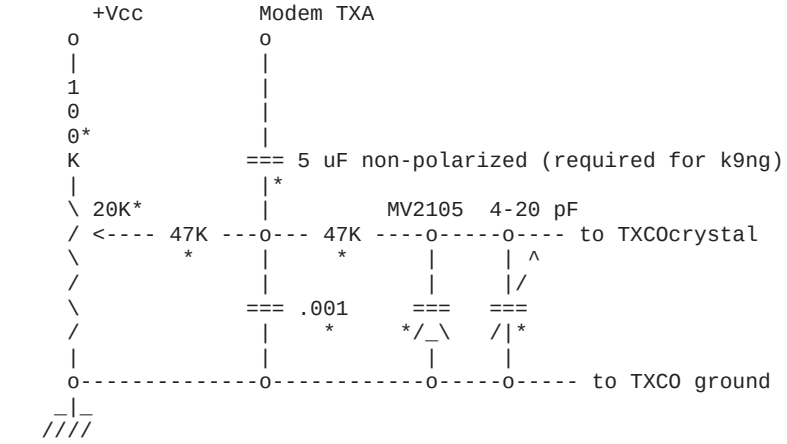
Connect 2 10K resistors to C-53 (both sides) and tie the other ends together. This junction is where you'll pick off your RXA.

Turn R-67 (dev control next to P-1 and P-2) completely counter-clockwise. This kills signals that may get into the phase modulator.

Using a service monitor, or oscilloscope connected to the detector of a receiver, adjust the varactor bias for the best eye pattern.

Alternate bias adjustment:Use the modems 4800 Hz "idle" tone to adjust your modulator for best linearity. Using a service monitor, or a receiver with a fairly wide passband, adjust varactor bias for the "best" sine wave. Thanks to Brian Kantor wb6cyt for this tip.

Transmit oscillator



4.1.4 IF FILTER CONSIDERATIONS

Quite a bit of confusion seems to exist concerning 9600 baud, channel width, and IF filters. 1200 baud requires a 20 KHz channel, just like voice, right? And 9600 is more than 1200 - right?

Right - but incomplete! 1200 baud uses audio tones and modulates these. We have three components: radio carrier, audio carrier, and data. But we don't do this with 9600 baud. We "eliminate the middleman"! Our data is applied DIRECTLY to the radio signal! There are no "audio tones". 9600

baud is more efficient with bandwidth. We have repeatedly measured it at 12 KHz, with negligible emissions outside of this! That's actually narrower than most voice repeaters!

Because of these missing facts, some believe that 9600 baud half sine NRZI FSK modulation (what we're using) must be wider than 1200 baud AFSK and voice signals, and therefore requires a wider IF filter. When we talk about using wider filters, this tends to reinforce this belief!

This is not the case.

Then why all the talk about wider filters if your signal isn't wider?

The 9600 baud signal uses a half cycle per bit. This begins as a square wave, so one bit of data is contained in a half square wave. A square wave can be represented as a sine wave plus all even harmonics. All k9ng protocol compatible modems use filters to remove these harmonics, resulting in each bit being a half sine wave. We're using 9600 bits per second; therefore the highest frequency component is a 4800 Hertz sine wave. (Most of the time, it's even less!)

Coupled with the optimal setting of 3 KHz deviation, we come up with an effective bandwidth of about 12 KHz. This has in fact been measured and verified using spectrum analysers by several knowledgeable people. It's actually slightly narrower than either 1200 baud packet or typical NBFM voice operation!

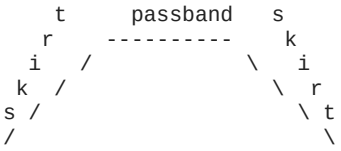
Then why do we "need" wider filters?

We DON'T need wider filters - we simply need LINEAR filters.

There are 2 common configurations for multipole IF filters - Chebichev and Butterworth. For a given number of poles, Chebichev filters are characterized by steeper skirts but ragged response (ripple). Butterworth filters are characterized by smoother response but broader skirts. It requires less poles (it's cheaper) to make a Chebichev filter for a given passband and skirt slope than a Butterworth - so guess which one gets used in most radios?

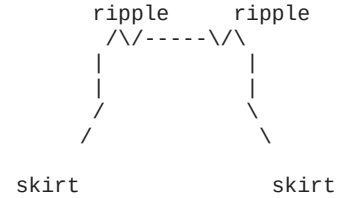
Here is an approximate response curve for Butterworth and Chebichev filters. Notice the steeper skirts on the Chebichev, and the "ripple" at the right side of the "flat top":

BUTTERWORTH FILTER RESPONSE



Notice how smooth the flat top (design passband) is! But look at those skirts! You could float an oil tanker sideways through those skirts!

CHEBICHEV FILTER RESPONSE



Now look at the nice, steep skirts of the Chebichev filter! If you can tolerate a little ripple, a Chebichev filter makes a lot more sense.

The ripple is at the high frequency edges, so if we use a wider filter, we can keep our signal in the non-ripple portion!

The distortion is most severe at the passband high frequency edge, so if we use a wider Chebichev filter, there is less distortion.

If we use a Butterworth filter, the ripple is gone - but the skirt is a lot broader! To make the shirt steeper and give us adequate selectivity, the filter manufacturer must use more "poles" (that's filter talk for "stages"), resulting in a more costly filter.

For voice, this is not really necessary. The audible difference is quite minimal, especially for amateur voice grade equipment. For digital radio communications, it's worth the extra cost to get the job done right.

There are filters designed especially for digital use, such as MuRata's SFG455 and SFH455 lines. MuRata didn't send specific design information, but I'd guess they use a Butterworth design in these. I've personally tested their digitally optimized filters, as narrow as 7.5 KHz @ -6 dB (the narrowest I have), and while tuning is rather critical, performance is flawless! Of course, this came as no surprise to MuRata's engineers.

4.2 TNC MODS

Your TNC will work better at 9600 baud if you speed it up. For TNC2 clones, change the Z-80 and Z-80 SIO to 10 MHz types, and change the clock speed by changing the jumper on JP1. Older ones use the 2 OUTER pins, and newer ones use the center and (other) outer pin.

4.3 MODEM MODS

Many rigs require a lot less TXA than the modem outputs, and a resistive swamping network may be needed. For example, the TEKK KS-900 wants 50 mV for 3 KHz deviation.

On the TEKK KS-900/PacComm NB96 combo, I use 470 ohms series, and 39 ohms across the TEKK's input terminal to ground.

If you need to externally mount your modem and use a ribbon cable, mount the modem header on the opposite (TOP) side of the PCB, or use a second short ribbon cable. Ribbon cables "flop" the pins, e.g.:

```
        1 3 5 7 9  _______________________________ 2 4 6 8 10
        2 4 6 8 10                                 1 3 5 7 9
```

By placing the connector on top rather than underneath, the flop is normalized.

4.3.1 K9NG MODS

Use the PTT from the TNC instead of the k9ng modem. This lets you use the TNC's watchdog timer, and makes things a lot simpler. Make sure to cut only the following traces between pads on your TNC-2's modem disconnect J4:

11/12 transmit clock
13/14 receive clock
17/18 receive data

The TNC-2 manual tells you to cut other traces, but by doing it this way, you'll be able to use the TNC's PTT circuit. The k9ng's keying circuit, which doesn't work all that well without modification (it's designed for the Hamtronics FM-5), may now be omitted from the pcb, if you like. This is most of the stuff on the lower edge of the pcb. The g3ruh modem already does this.

From Brian Kantor wb6cyt@wb6cyt.#soca.ca.usa.noam:
To summarize my mods to the K9NG modem:

Data-derived RX Clock may be derived from U4 pin 9.

Half an LS02 can be used to buffer and gate RXD and RXC with DCD/, which will really cut down on the number of frame aborts in the switch or TNC.

R-31 should be changed to around 680 ohms, and C18 should be increased to .1 uF to improve the DCD circuit. (changed per note below)

If you don't have a 16x or 32x clock available, a 4060 and a 4.9152MHz crystal will get you one for about $3 total.

At 4800 bps, no changes are needed to the input RCV Filter, but at 9600 bps, the capacitor values are quite critical because the low-pass filter cutoff is too close to 4800 Hz. If your radio has a decent IF, you can just cut the values down and you'll get fewer damaged received packets. (In fact, what I do is reduce C13/14 from a parallel combination of 2700 and 1800 pf to just the 2700 pf, and use the single 1800 pf left over instead of C15/16, which used to be 2200pf + 56pf.)

Change C19, a 220uF capacitor, to ~ 6uF to avoid frying the regulator.

For a TNC-2, jumper the modem header pin 3 to pin 4 so that Net/Rom can find itself. Don't cut the jumper on 9-10, so that the keying circuit inside the TNC will continue to work. Do cut the jumper on 7-8. Putting a jumper across 1-2 will let the DCD light on the TNC work.

Hanging a diode from U2 pin 6 to the RTS/ line (solder it from the right-hand side of R26 to the right-hand side of D3) will inhibit the DCD/ output while you're transmitting, which might confuse things. Note that because of the hang time of the DCD circuit, you WILL get a brief burst of DCD after you unkey, but that's unlikely to cause any problems even in a critical device driver, since you will have already told the interface to deassert RTS/, and presumably you're therefore ready for incoming carriers.

Oh, and of course you can leave out all the stuff after U6 pin 10 and U2 pin 14. That's all just DC switching stuff that you won't need if you're using the TNC's PTT or some external PTT. If you are using the modem without a TNC, you can use U6 pin 10 to drive a transistor, or a 555 and a transistor if you need a blab-off.

To turn the modem into an FSK regenerator for real-time digital repeating, cut the trace from U7-1 to U8-13, and connect U7-1 to U2-2. That will push received data up the transmit modulation channel whenever RTS/ is not asserted.

- Brian

My oh-so-wonderful mod for the K9NG modem appears to be not so wonderful. I've been replacing the 470 ohm resistor in the carrier detect circuit with a short, and increasing the .047 cap in there to .1 uf. The cap change is ok, but shorting out the resistor makes the CD output go false on even ONE error pulse from the DPLL, yet the DPLL isn't really getting an error quite that quickly - Mike guesses that 3 or 4 consecutive clocks of the error output can occur before the DPLL is in trouble. So we want to integrate the error output to cancel DCD rather than do so on only one error pulse. To do that, replace the wire with a small resistor. Around 1K, the modem falses DCD on noise too much. I found the optimum value seems to be around 750 ohms or so, but since I don't have any of those, I'm using 680 ohms. My 9600 and 4800 bps links have been working noticeably better!

- Brian

4.3.2 G3RUH MODS

PacComm NB96 MODS

by Mike Curtis wd6ehr

The PacComm NB96 g3ruh modem has a jumper-selectable "defeat", JPS. When a jumper is in position here, the modem disconnect is normalled through. I've installed a DPDT slide switch on the front of my MFJ 1274 to make radio baud rate changes simple. The first pole is used to make the connection to JPS. The second pole is used to change the radio baud rate selection normally made by the rear panel DIP switch. If your modem has its own clock, the radio-baud-rate switch is unnecessary.

A quick and dirty external DCD LED can be easily added to PacComm's NB96 9600 baud modem board. Pin 13 on U-10 supplies a DCD signal. Connect a 680 ohm resistor and LED between this and +5 volts, obtainable on pin 24 of S-1 or S-1a, both 26 pin connector positions on the PCB. Only one is used. Solder your +5 volt wire into the unused hole of the other, run this to the 680 ohm resistor, connect the other end of the resistor to the LED anode, and the cathode of the LED to U-10 pin 13.

If you plan on using your TNC for 9600 baud only, the following mods mute the NB-96 modem TXAudio:

1. On the back of the modem board, cut the trace from the base of surface mount transistor Q2. Looking at the bottom of the modem, with P-5 at the top, Q1 and Q2 are in the upper left corner. The base of Q2 is the bottom lead on the right.

2. Install a wire from the base of Q2 to S1 (the 26 pin modem disconnect header) pin 5 or 9 (RTSA).

3. Cut the trace coming from pin 2 of the SPTX jumper (TX Aiudio attenuator selector)

4. Connect this pin 2 to U-21 pin 5.

5. Remove the 1200 baud modem chip from the TNC (I assume this applies if you're using the TNC's radio connector)

THIS 2ND MOD ALLOWS USING THE TINY-2 DIN PLUG FOR TX & RX AUDIO USING AN INTERNAL NB96 BOARD.

This mod allows using the 5 Pin DIN plug for the radio to TNC interface as opposed to having to use seperate shielded cables coming directly off P5 of the NB96 internal modem card.

1) When looking at the back of the 5 Pin DIN plug on the Tiny-2 Main board, you will see two traces. One comes off Pin 1, the other off Pin 4. These are the normal TX Audio out and RX Audio in connections if you were going to use the internal 1200 Baud modem. (Normal Mode)
2) Cut both traces. (Just for reference, both traces go under R20 which is mounted directly behind the DIN plug.)
3) Solder the Center of the TXA cable from P5 of the NB96 right to the back of the DIN Plug at Pin 1.
4) Solder the Center of the RXA cable from P5 of the NB96 right to the back of the DIN Plug at Pin 4.
That's it. Now you can use the DIN Plug for the radio connection at 9600.

***BOTH MODS ABOVE ARE ONLY GOOD IF YOU ONLY PLAN TO USE THE TNC @ 9600 ***

Courtesy of Joel wa1zyx@wa1ytv.nh

4.3.2.1 G3RUH "GARBAGE" MOD

by Steve King kd7ro

(note: some garbage is caused by serial port overruns, improperly shielded serial cables, and non-buffered UART's. This mod will not fix these - mc)

Gets rid of random garbage "calls" in MHeard
This mod makes sure that the modem will send all zeros to the TNC until the modems PLL is locked on a signal. This means that the TNC will not be reading garbage coming in to the UART all the time.

1. Remove socket for U11 (74HC14)
2. Insert the 74HC14 directly into the PC board.
3. Lift all the pins of a 74HC00 except 7, 12 and 14.
4. Bend pins so they are pointing straight out.
5. Cut back the bent pins so the 74HC00 can be piggybacked on the 74HC14.
   Without removing the socket on U11, I would not have been able to slide the modem and Tiny-2 back into the box (you may not have this problem).
6. Cut the trace from U11 pin 12 to U20 (74HC157) pin 13.

7. Solder the 74HC00 on top of U11 (soldering pins 7, 12 and 14).
8. Wire U10 pin 13 (LM339) to the 74HC00 pins 9 and 10.
9. Wire 74HC00 pin 8 to pin 13.
10. Connect pin 11 of the 74HC00 to pin 1 and 2 of the 74HC00.
11. Connect pin 3 of the 74HC00 to pin 13 of U20 (74HC157).
12. Put a piece of tape over the top of the 74CH00 to insulate from the case.

The DCD signal coming from U10 (LM389) is low true so I invert it using one of the nand gates (pins 8, 9 and 10). This is used to qualify the RXD signal from the 74HC14 (pin 12). Pin 11 of the 74HC00 is the RXD signal (low true) qualified by the DCD signal which is LOCK DETECT. One more inversion of this signal (74HC00 pins 1, 2 and 3) and I have the qualified RX DATA signal which is connected to U20 (74HC157) pin 13.

RX DATA is always zero until the PLL is locked to the data. Then RX DATA will be the true data coming from the unscrambler or zeros if we are not locked.

-o-

Another cause of garbage is serial port overrun. I highly recommend using a 16550AFN UART serial card, and software that supports it. This has a 16 bit FIFO buffer, and saves bits that would normally be lost when the CPU turns the serial port off, and expects it to react instantly, but doesn't.

4.4 MODEM INSTALLATION

The k9ng and g3ruh 9600 baud modems require HDLC packet at TTL levels. On most TNC's, this is obtained at the modem disconnect header. On TNC1,s and TNC2's, this is a 20 pin header, with the odd numbered pins on one side going to the TNC, and the even numbered going to the TNC's built in modem(s).

As you might expect, this allows us to disconnect the built-in modem and install our external modem.

4.4.1 TNC2 CLONES

For MFJ's, PacComm TNC220, and other true TNC2 clones, you'll usually need to install the modem disconnect header plug. This is a 20 pin (two rows of ten pins each) male connector.

You'll also need to cut some traces on the underside of the TNC printed circuit board (PCB). Carefully cut the traces connecting these pins ONLY. DON'T cut traces going to other parts of the board:

TXClock	11-12
RXClock	13-14
RXData	17-18

If you're installing the modem inside the TNC, mount its connector UNDERNEATH the modem. If it's to be mounted externally with a ribbon cable, mount it on TOP of the modem board!

4.4.2 PK-87/PK-88

The PK-87 has an external modem jack J-4. Make the following connections to it:

MODEM	PK-87	PK88	FUNCTION
1	5	14	DCD
11	3	13	TXClock: some PK-87's and older PK-88's use a 9600 Hz (x1) clock. Wire a x16 clock from U-20 pin 11 to this pin and cut the old trace.
15	2	17	Ground
17	4	15	RXData

```
19      1     16    TXData

Note:  This may or may not apply to your TNC.  Read your manual and follow
its' instructions, or phone AEA if you need help.

5       9600 BAUD PARAMETERS

   As you'd expect, the parameters we all know and love at 1200 baud can
be improved upon at 9600 baud.  These are what I've been using, but feel
free to experiment - these are not etched in stone.

5.1            AX.25 PARAMETERS

TXDelay        depends on your rig and recovery time of the slowest
               station on channel that you wish to work; try between 5
               and 15 - set for best throughput with all
RESPtime       100 mS seems to have better results than 0
FRack          5 seconds or more on a busy channel; 2 on a less busy channel
PERSIST        (256/users)-1; if it's a pretty clean channel, 63 is
               nice; if it's busy, guesstimate the average number
               of users active at one time, divide 256 by this number,
               then subtract 1, i.e. 4 users = (256/4) =64 -1 = 63
SLOTTIME       10
MAXFrame       1

5.2             TCP/IP PARAMETERS

Here are parms from my files.

ax25 maxframe 1
ax25 pthresh 64
ax25 t3 300000
ax25 t4 3000000

param ax0 1 12
param ax0 2 63
param ax0 3 10
param ax0 4 3

 If you have a very good path to all stations, throughput can be greatly
increased by using larger mtu, tcp mss, and tcp window sizes.  However,
it's probably best under normal conditions to run these at 256, 216, and
512 respectively.


6               HELP

 Should you require help in getting 9600 baud up and going, I'd be more than
happy to help out, time and circumstances permitting.  Feel free to phone or
write, or send a note to wd6ehr@k6ve.#soca.ca.usa.  Currently, I'm severely
backlogged with schematics.  Most of these are modulated inside the PLL
and require quite a bit of research, and even then, it's quite difficult to
tell whether it will work without a unit here to test.  I will eventually
get to these, but it may be a very long time.

7       TERM GLOSSARY

AFSK
               Audio frequency shift keying - uses multiple audio tones,
               like a telephone modem.

DISCRIMINATOR
               generic term for _any_ FM detector, i.e. discriminator, ratio
               detector, quadrature detector, Foster-Seeley detector, etc.

FIFO BUFFER
               First In, First Out (as opposed to a "stack", where the
               last in is the first out, like a stack of dinner plates)
               A temporary storage area (buffer) for serial ports, etc.

FREQUENCY MODULATION
               Modulation that shifts the frequency, i.e. applying a DC
               voltage will shift the signal xxx Hz, and keep it there.
```

FSK
Frequency shift keying - moves the RF frequency of the carrier; uses no audio "tones"; raw data is DC coupled directly to the modulator and the frequency is shifted according to the data.

PHASE MODULATION
Modulation that shifts the frequency instantaneously, but then returns to the original frequency, i.e. applying a DC voltage will shift the frequency for one Hz (or whatever the rise time of the DC voltage is), and then allow the frequency to return to it's "center" value. Phase modulation is not good for the type of 9600 baud we're currently doing, because current demodulators are FM.

PLL
Phase Lock Loop. A chip or circuit used in frequency synthesizer circuits, in which an oscillator signal is divided down to a reference frequency and fed to a phase detector, which locks this to a reference crystal. Generically used

UART
Universal Asynchronous Receiver-Transmitter - the chip used to convert parallel data inside the computer to serial data for the RS-232 or other serial port

8 CREDITS

As in any major undertaking, the information in this manual is not a unilateral project. Many, many people have contributed in one way or another. Some of these are:

fellow "Baud Brothers" Frank Andersen w7zta and Dave Shalita w6mik; Brian Kantor wb6cyt, Don Lemke wb9mjn, Orv Beach wb6wey, James Miller g3ruh, and lots of others! Thanks, guys - from ALL of us!

Mike Curtis, wd6ehr
wd6ehr@k6ve.#soca.ca.usa.noam
7921 Wilkinson Avenue
North Hollywood CA 91605-2210